FORESTRY 050

Losses in Timber Values Associated with Distorted Growth in Immature Douglas-fir

ISSN 0835 0752

JANUARY 1989

ECONOMIC & REGIONAL DEVELOPMENT AGREEMENT

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Losses in Timber Values Associated With Distorted Growth in Immature Douglas-fir

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January 1989

ECONOMIC & REGIONAL DEVELOPMENT AGREEMENT

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89-02957/

Funding for this publication was provided by the Canada-British Columbia Forest Resource Development Agreement - a five year (1985-90) $300 million program cost-shared equally by the federal and provincial governments.

Canadian Cataloguing in Publication Data

Main entry under title:
Losses in timber values associated with distorted growth in immature Douglas-fir

(FRDA report, ISSN 0835-0752 ; 050)

Issued under Forest Resource Development Agreement.
Co-published by B.C. Ministry of Forests.
"Canada-BC Economic & Regional Development Agreement".
Bibliography: p.
ISBN 0-7726-0913-6

1. Douglas-fir - British Columbia - Vancouver Island - Growth. 2. Forests and forestry - Valuation - British Columbia - Vancouver Island. I. Middleton, G.R. II. Canada. Forestry Canada. III. British Columbia. Ministry of Forests. IV. Forest Resource Development Agreement (Canada). V. Canada-BC Economic & Regional Development Agreement. VI. Series.

SD397.D7L67 634.9'754285 C89-092050-8

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This is a joint publication of Forestry Canada and the British Columbia Ministry of Forests.

Produced and distributed by the Ministry of Forests, Research Branch.

For additional copies and/or further information about the Canada-British Columbia Forest Resource Development Agreement, contact:

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SUMMARY

Lumber yields from a sawmill recovery study were used to quantify variation in tree values associated with growth distortion, prevalent in two stands of late immature Douglas-fir located in the Wetter Maritime CWH biogeoclimatic subzone on the west coast of Vancouver Island, British Columbia. The objective was to gain preliminary information on the variation in timber values associated with distorted growth (sinuosity and branching), to establish sampling requirements for the development of statistically significant value-based stem distortion classes.

Following preliminary sampling of 200 potential study trees, 42 were selected according to size, branching, and sinuosity. These trees were felled, transported to a sawmill, and converted to lumber. Lumber grade and volume yields were recorded and used to calculate values for each study tree. These values were found to be 43% lower than those obtained in a previous second-growth Douglas-fir study. This lower value, however, was due primarily to rapid rates of growth in the distorted trees, which resulted in lumber that failed to meet annual ring count requirements for No. 2 and higher structural grades.

Analysis of variance was used to test preliminary branching and sinuosity indices for their effect on tree value. The test, although not statistically significant, indicated that it should be possible to establish differences in value between moderate and severe classes of both sinuosity and branching. Trees classed as severe for either trait had an average value that was approximately 10% lower than that of trees classed as moderate for both traits. The two traits had a cumulative effect on value, such that trees that were classed as severe for both had an average value that was 20% lower than trees classed as moderate for both. Based on the variation in tree values recorded in the study, it was determined that a minimum of 20 trees per class would be required to establish statistically significant differences in average tree values between moderate and severe sinuosity and branching classes.

To investigate the possibility that growth distortion could result in an increase in drying defects, lumber obtained from the distorted trees was kiln dried . Drying resulted in a significant occurrence of crook in the widest lumber (2 x 8), but there was no discernible relationship between drying degrade and degree of sinuosity.

Further sampling is recommended to confirm the results of this study, and to determine if the indices developed here are based on the most appropriate criteria for assessing the effect of growth distortion. Some quantitative testing should be undertaken to determine if growth distortion is generally associated with very rapid rates of growth, and engineering tests should be undertaken to confirm that visual grades assigned with respect to excessive growth rate are indicative of actual lumber strength values. Research should also be undertaken to develop modified drying practices for reducing warp that occurs when lumber from second-growth Douglas-fir is kiln dried.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support of this project received from the Canada - British Columbia Forest Resource Development Agreement. The support of MacMillan Bloedel and CIP Inc. is also gratefully acknowledged.

We thank Mr. P. Affleck, MacMillan Bloedel, and Mr. D. Webb, CIP, for their help in arranging the field work; Dr. P.L. Cottell, MacMillan Bloedel Research, Dr. J. Dobie, Statistics Canada, and Mr. R.N. Green, B.C. Ministry of Forests, for their review of the working plan and this manuscript; and Dr. J. Cook, Forintek Canada Corp., for her advice on the sample design.

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1 INTRODUCTION

Growth distortion is prevalent in immature Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, growing on cool wet sites in southwestern British Columbia. It is a serious concern to foresters who must estimate its probable impact on future stand values if they are to make correct decisions about remedial stand management.

Growth distortion has been the subject of several recent studies (Hoyer 1983; Carter *et al.* 1986; Carter and Klinka 1986). These studies have identified probable causes for specific growth distortion symptoms, and their pattern of occurrence in relation to site conditions. Undesirable growth form characteristics of Douglas-fir appear to increase with increasing soil moisture and with soil nitrogen availability. The highest incidence of distorted growth in Douglas-fir has been found within the Windward Sub-montane variant of the wetter Coastal Western Hemlock biogeoclimatic subzone (CWHb1), where neither the climate nor the edaphic conditions are considered to be suitable for Douglas-fir (Carter and Klinka 1986). Two symptoms of growth distortion found to be most prevalent in this variant are excessive and oversized branching, and stem sinuosity. This study concentrated on quantifying the severity of these symptoms in terms of their effect on sawmill yields.

The study was carried out in late, immature Douglas-fir stands on two sites, Franklin Camp and Pachena River, located on southwestern Vancouver Island in British Columbia (Figure 1). The stands differed in age, initial spacing, and site conditions. The Franklin site was a 35-year-old plantation, growing on mixed fluvial and colluvial materials, with a fresh soil moisture regime and medium actual soil nutrient regime. Initial spacing was 6 x 8 ft. The Pachena site was a 25-year-old plantation growing on glacial marine materials, with a moist-to-wet actual soil moisture regime and medium actual soil nutrient regime (Klinka *et al.* 1984). Initial spacing on this site was 10 x 10 ft. There were no subsequent stand treatments on either site. Both stands were in the CWHb1,2 biogeoclimatic subzone (Klinka *et al.* 1979), and the results of this study are expected to be generally applicable to other immature Douglas-fir stands in same variant.

To ensure that the effect of growth distortion on timber value could be comparatively assessed, the methods used in this study duplicated those used in a previous conversion study of approximately 300 second-growth Douglas-fir trees (Middleton and Munro 1988). The trees in the previous study, hereafter referred to as the second-growth Douglas-fir study, ranged in age from 40 to 60 years, and were selected because they exhibited a rapid but uniform rate of growth from pith to bark — a characteristic considered to be desirable as a stand management objective. The 300 trees were obtained from six different stands and three different regions on Vancouver Island.

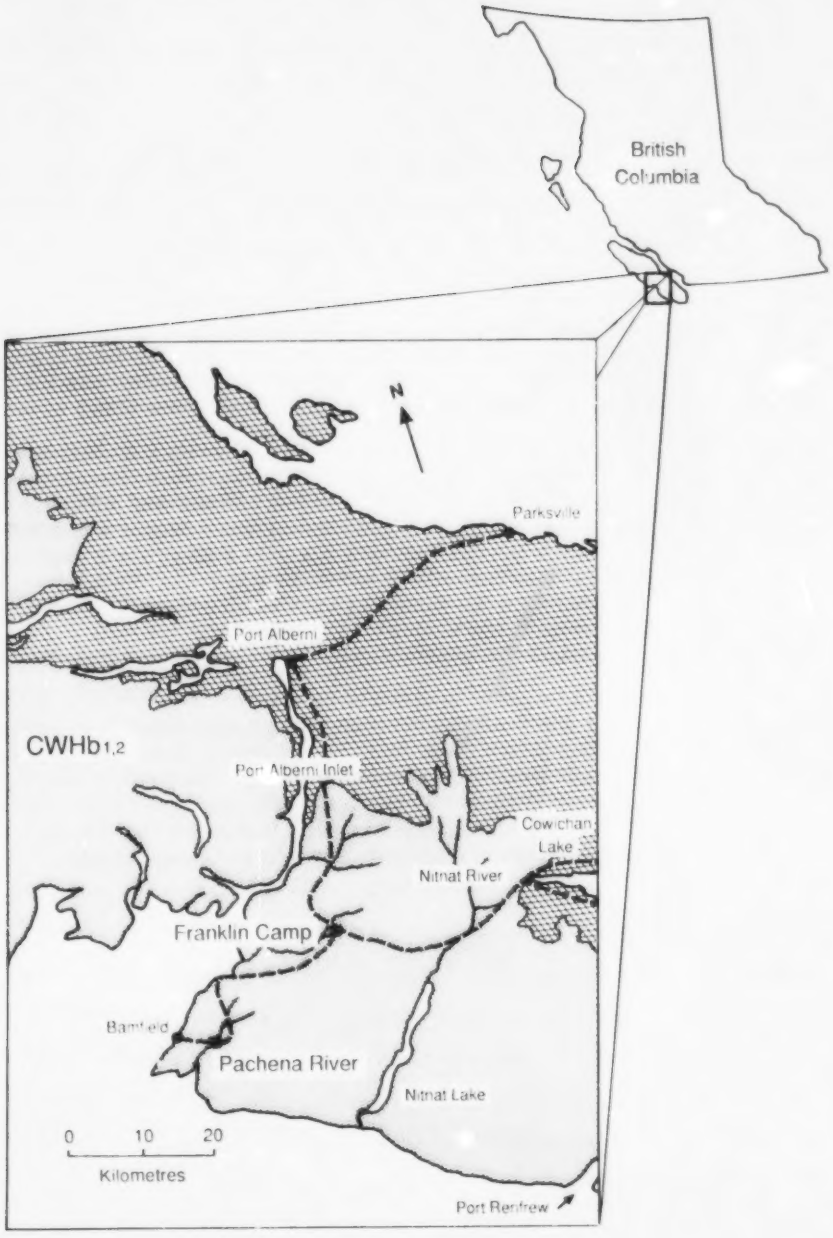

FIGURE 1. Sample site locations.

2 OBJECTIVE

The aim of the study was to gain preliminary information on the variation in timber values associated with distorted growth (sinuosity and branching), so that stem distortion classes could be established for a survey of the extent of the growth distortion problem.

3 METHODS

3.1 Definition of Terms

Sinuosity	Departure of the main stem axis from a straight line between any two whorls.
Crook	Departure of the main stem from a line between any two or more whorls, where the departure originates in a branch whorl rather than on the interwhorl.
Frequency	The maximum number of oscillations in an interwhorl segment (Figure 2).
Displacement	The largest distance that the stem is offset from the position it would occupy if it had no sinuosity. This distance is measured in half-stem units and is used to calculate a sinuosity index (Figure 2).
Sinuosity index	Frequency multiplied by displacement.
Primary branch number	The number of branches greater than 1 cm in diameter found on the main stem in each main whorl (Figure 2).
Interwhorl branch number	The number of branches greater than 1 cm in diameter occurring in the main stem between two whorls (Figure 2).
Branch diameter	The mean diameter of all primary branches measured with steel calipers from upper to lower surface at a point 2.5 cm from the main stem.
Branching index	The branch number class multiplied by the branch diameter class.
Branch area	Area of each branch measured at whorls one and two, multiplied by the average number of branches at those whorls.
Lumber recovery factor (lrf)	Volume of lumber in board foot measure divided by log or tree volume measured in m^3.

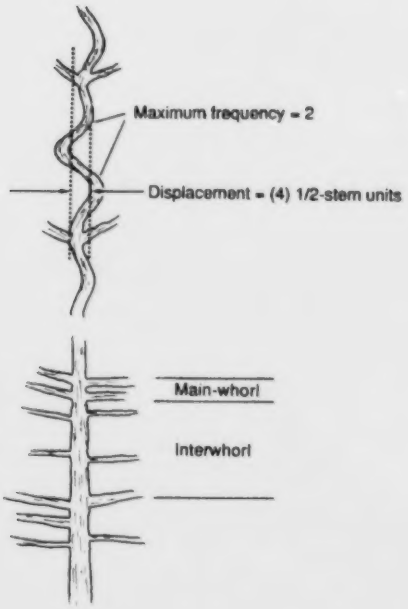

FIGURE 2. Stem sinuosity and branching.

3.2 Tree Selection

The cost of whole tree conversion studies dictated the need for a systematic sampling plan that would yield maximum information from a minimum number of trees. Results from previous conversion studies suggested that a sample of 40 trees would be sufficient to reveal the variation in tree values associated with growth distortion, provided the sample was carefully distributed over the range of distortion present. It was decided that sampling would be undertaken in three stages:

1. Preliminary sampling would be undertaken to determine the range of growth distortion present in each stand.
2. Potential candidate trees for a conversion study would be identified from the preliminary sample.
3. Final selection of study trees would be based on obtaining a balanced distribution of the range of distortion present.

3.2.1 Preliminary sampling

In each of the Franklin and Pachena sites, 100 trees were marked at random along transits and the following measurements and observations were made on each tree:

- total height
- diameter at breast height outside bark (dbh)
- number of branches per whorl (first five whorls)
- branch diameter (first three whorls above breast height)
- presence of forks
- presence of crooks
- presence of sweep in the main stem.

The following methods were used to characterize the range of sinuosity and branchiness present, and to calculate a sinuosity index and a branching index for each tree:

Sinuosity: (Each tree was classified by two observers standing 90° apart.)

Frequency:

(1) Little or no observed sinuosity
(2) Frequency ≤ 1
(3) Frequency > 1 ≤1.5
(4) Frequency > 1.5 ≤ 2

Displacement:

(1) ≤ 1
(2) > 1 ≤ 2
(3) > 2 ≤ 3
(4) > 3 ≤ 4
(5) > 4

Branch number:

Number of primary branches per whorl:

(1) < 6
(2) 6 - 9
(3) 10 -14
(4) > 14

Branch diameter:

Mean diameter of primary branches in the first three whorls above breast height is:

(1) ≤1.5 cm
(2) ≤ 2.5 cm
(3) ≤ 3.5 cm
(4) ≤ 4.5 cm
(5) > 4.5 cm

3.2.2 Candidate trees

Candidate trees were limited to those which had no severe forks in the lower two-thirds of height, and to trees for which height and dbh measurements fell within 1 standard deviation of the mean height and dbh for all sample trees. Trees with severe forks were excluded, because forks significantly reduce tree value which, in a small sample, would only confound efforts to evaluate the effect of sinuosity and branching. Trees were chosen over relatively narrow ranges of dbh and height, to limit the effect that differences in size have on average value. Plus or minus 1 standard deviation of the overall mean dbh was 28.5 - 44.1 cm, and plus or minus 1 standard deviation of the overall mean height was 19.4 - 27.9 m.

The preliminary sample yielded a total of 81 trees that fit the above criteria. Forty-six were located on the Pachena site, and 35 at Franklin. These candidate trees were sorted by branch area and sinuosity index to aid in the selection of the 40 trees to be used in the conversion study.

3.2.3 Study trees

Twenty of the candidate trees were marked for felling at each of the two sites. The last sampling criterion was satisfied during this selection. Five trees were selected from each of the upper and lower 15th percentiles of the calculated sinuosity and branching indices, to ensure representation of the extremes in both branchiness and sinuosity. The remaining 20 trees were chosen so that a continuous distribution of branching and sinuosity could be achieved between the extremes.

Hang-ups that occurred during tree felling at the Pachena site required that some additional trees be felled. This provided an opportunity to add two candidate trees to the study, and increased the final sample size to 42 trees.

3.3 Log Measurements

The study trees were felled and bucked in the woods according to utilization standards and log manufacturing instructions consistent with those used in the second-growth Douglas-fir study. The preferred log lengths were 10 and 12 m. Prior to bucking, the following measurements were made to characterize the stems further:

1. number and diameter of all primary branches at each of the first five whorls above breast height;
2. number of intermodal branches below each of the first five whorls above breast height;
3. sinuosity (frequency and displacement) for each of the first five interwhorls above breast height;
4. kind, cause (where identifiable), and whorl of occurrence of distorted growth traits found on the main stem (i.e., forks, crooks, double whorls, ramicorn branches);
5. diameter 5 cm above and 5 cm below the centre of each of the first five whorls above breast height;
6. diameter at breast height; and
7. height to the base of the live crown, total tree height, and height to the centre of each of the first five whorls above breast height.

Each merchantable log was tagged following bucking for identification. The logs were transported to CIP's sawmill at Ladysmith for milling. There the logs were scaled and graded on a dry land sort by qualified scalers from the B.C. Ministry of Forests, in accordance with rules described in the B.C. Ministry of Forests Scaling Manual (B.C. Ministry of Forests, 1982). The logs were hand-bucked to shorter mill-run lengths, and log-end diameters were measured to the nearest 1 mm to allow accurate classification by top diameter.

3.4 Conversion Study

The study logs were processed through CIP's Ladysmith sawmill, which had been used to process logs sawn in the second-growth Douglas-fir study. The sawing strategy was to obtain a centre cant of maximum width, and to cut dimension lumber only. The sawmill was equipped with a quad-band headrig, a double-arbor circular saw edger, and a board edger. A schematic diagram of the mill equipment, with saw kerfs indicated, is shown in Figure 3.

A milling sequence number was assigned to each log and used to identify the lumber produced. Colour codes were used to keep track of the log sequence and to help identify the lumber by sequence number. Lumber grades and dimensions were estimated and recorded prior to trimming. The lumber was graded by a qualified grader (the same grader as was used in the second-growth Douglas-fir study) according to NLGA standard grading rules for structural lumber (NLGA 1987). Reasons were recorded for each grade assigned.

3.5 Drying Study

Because there is likely to be a trend toward the marketing of Douglas-fir as kiln-dried lumber, a subsample of 2 x 6 and 2 x 8 study lumber was selected for a lumber drying study intended to determine if stem sinuosity would cause an increase in drying degrade. The study was undertaken by Forintek Canada Corp. at its Western Laboratory located in Vancouver, B.C.

A total of 309 pieces of 2 x 6 and 229 pieces of 2 x 8 lumber was kiln dried using a moderate schedule. The lumber was subsequently examined for the following drying defects: bow, crook, cup, and twist.

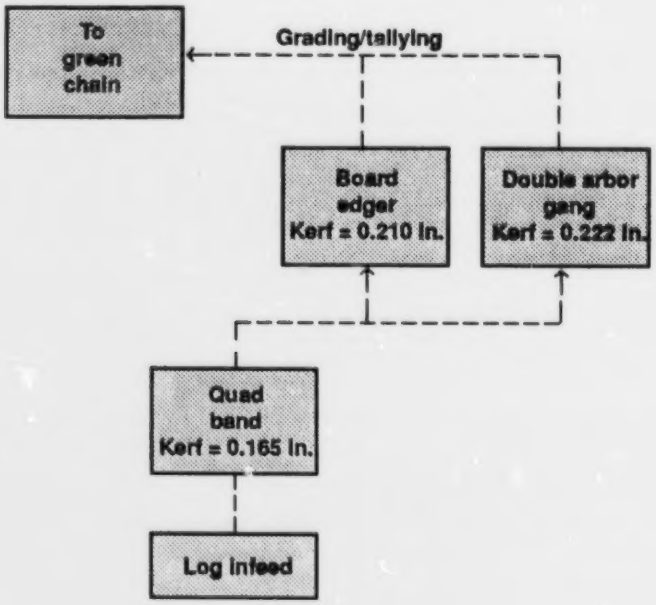

FIGURE 3. Sawmill equipment and sawing kerfs.

4 RESULTS AND DISCUSSION

4.1 Stand Characteristics

Statistics descriptive of the Franklin and Pachena stands are provided in Table 1. These were derived from the two random samples of 100 trees examined during the preliminary sampling. In general, the younger Pachena trees were shorter and had greater taper, larger branches, and more forks and crooks; while the Franklin trees had more sweep and sinuosity. The larger branches and equivalent average dbh of the Pachena trees can be attributed to their wider spacing. Diameter-height relationships are compared in Figure 4.

TABLE 1. Mean stand characteristics[a]

Site	Dbh (cm)	Height (m)	Branches			Sinuosity			Forks %	Crooks %
			No.	Dia. (cm)	Area (cm^2)	Freq.	Disp.	Index		
Pachena River	36.7 (7.6)	19.9 (2.2)	6.5 (1.6)	3.0 (0.7)	48.6 (27.1)	2.3 (0.9)	2.0 (0.7)	5.0 (3.1)	30.3	19.2
Franklin Camp	36.1 (8.2)	27.3 (2.0)	7.0 (1.3)	2.3 (0.7)	32.1 (24.5)	2.6 (1.0)	2.1 (0.7)	6.1 (3.7)	17.3	13.3
Combined	36.4 (7.9)	23.6 (4.3)	6.7 (1.5)	2.6 (0.8)	40.4 (27.1)	2.5 (1.0)	2.1 (0.7)	5.5 (3.5)	23.9	16.2

[a] Numbers in parentheses are standard deviations.

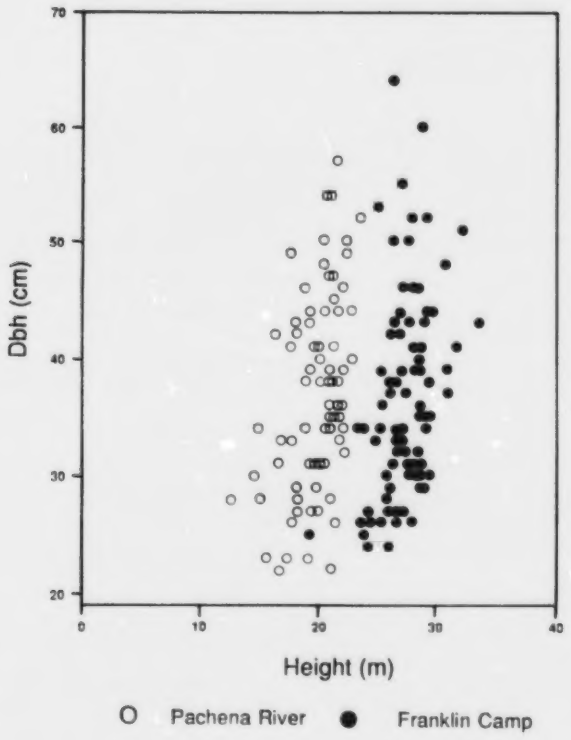

FIGURE 4. Tree dbh-height relationships.

4.2 Sample Trees

Statistics descriptive of the 42 study trees selected for the conversion study are shown in Table 2. When compared with those of Table 1, these statistics indicate how well the study trees represented the average quality of trees in the two stands. In most respects the study trees were representative despite the systematic sampling plan necessary to achieve the desired distribution of sinuosity and branching. The study trees were somewhat larger in average dbh, but were of similar average height. Branchiness and sinuosity statistics were reasonably comparable.

The greatest difference between the study trees and the average tree in the stands resulted from the decision to exclude trees with severe forking from the final sample. Approximately 30% of trees on the Pachena site and 17% of trees on the Franklin site contained forks, 83% of which were located in the lower two-thirds of the stem. Although 16% of the study trees had forks, nearly half of these were located in the top third of the stem and none were located in the lower third. Because forks significantly affect log yields, the average values obtained for the sample trees are higher than what could be expected from trees generally available on these two sites.

Table 3 shows how the trees obtained for the conversion study at each selection site were distributed according to branching and sinuosity indices. Reasonably good representation of the extremes of branching and sinuosity were obtained, but tree distribution was somewhat clumped in terms of branching. Approximately 50% of the trees selected at the Pachena site fell into a branching index of 6, while 50% of the Franklin trees fell into a branching index of 4. This was the result of generally uniform branching characteristics on each site. The two distributions are shown combined in Table 4.

TABLE 2. Mean study tree characteristics[a]

Site	Dbh (cm)	Height (m)	Branches			Sinuosity			Forks %	Crooks %
			No.	Dia. (cm)	Area (cm^2)	Freq.	Disp.	Index		
Pachena River	38.3 (4.4)	20.9 (2.1)	6.9 (2.0)	3.0 (0.5)	52.1 (28.5)	2.3 (0.9)	2.1 (0.8)	5.3 (3.3)	18.2	22.7
Franklin Camp	40.4 (6.6)	27.5 (1.6)	6.8 (1.2)	2.7 (0.9)	45.7 (37.0)	2.9 (1.1)	2.3 (0.8)	7.3 (4.7)	15.0	5.0
Combined	39.3 (5.6)	24.0 (3.8)	6.8 (1.6)	2.9 (0.7)	49.0 (32.6)	2.6 (1.0)	2.2 (0.8)	6.2 (4.1)	16.7	14.3

[a] Numbers in parentheses are standard deviations.

TABLE 3. Site distributions of sample trees by sinuosity and branching indices

Pachena River

Branching Index	Sinuosity Index						Total
	1	4	6	8	9	12	
2	1	1	-	-	-	-	2
3	1	-	-	-	1	-	2
4	-	1	-	-	-	1	2
6	2	4	3	1	3	-	13
8	1	1	-	-	1	-	3
Total	5	7	3	1	5	1	22

Franklin Camp

Branching Index	Sinuosity Index						Total
	1	4	6	8	12	20	
2	-	1	-	-	1	-	2
4	1	1	3	1	3	1	10
6	1	2	3	-	1	-	7
8	-	1	-	-	-	-	1
Total	2	5	6	1	5	1	20

TABLE 4. Combined distribution of sample trees by sinuosity and branching indices

Branching Index	Sinuosity Index							Total
	1	4	6	8	9	12	20	
2	1	2	-	-	-	1	-	4
3	1	-	-	-	1	-	-	2
4	1	2	3	1	-	4	1	12
6	3	6	6	1	3	1	-	20
8	1	2	-	-	1	-	-	4
Total	7	12	9	2	5	6	1	42

4.3 Conversion Yields

4.3.1 Log volume and grade yields

The B.C. Ministry of Forests provides taper equations and cruise grading rules for predicting the usable volume and quality of standing timber (B.C. Ministry of Forests 1982). Volume predictions and actual yields for the study trees are included in the statistics provided in Table 5. Based on the Ministry's taper equation for immature Douglas-fir, the predicted usable average tree volume for the combined sites was 1.04 m^3, while the actual recovered volume based on log scale was 0.92 m^3. The greater discrepancy was on the Pachena site where the taper equation predicted an average tree volume that was 0.16 m^3 greater than that recovered. The average volume discrepancy was 0.06 m^3 for trees from the Franklin site. This better correspondence results because those trees were closer to the average age and form upon which the equation is based.

Table 6 compares actual log grade yields to estimates based on cruise-grade rules. Comparisons are based first on a 10-m log length, the standard used in cruising, and then on a 12-m length which was the preferred bucking length in this and the second-growth Douglas-fir study. Although some I grade logs were predicted, the actual yield was confined to J and X grade logs — the former a good quality small sawlog, the latter a poor quality sawlog one step above pulpwood. The cruise-grading rules over-estimated the quality of the distorted trees, predicting a volume yield of between 95 and 100% J grade compared to an actual yield of less than 65%.

Table 7 shows how log volumes were distributed by J and X grades over the range of tree dbh classes sampled. The low yield of J grade volume obtained from the five trees that were 45 cm or greater in dbh significantly reduced the overall average volume yield of J grade logs.

Differences in the quality of J and X logs are indicated in the mean log diameters and recovery and value statistics provided in Table 8. In this study, J grade logs were somewhat larger than X grade logs, had a slightly higher recovery factor, and were worth about 20% more in average value.

TABLE 5. Tree volume and value statistics[a]

Site	Volume		Average value	
	Predicted (m^3)	Recovered (m^3)	($)	($/$m^3$)
Pachena River	0.85 (0.20)	0.69 (0.19)	17.64 (5.69)	25.75 (5.94)
Franklin Camp	1.24 (0.43)	1.18 (0.35)	32.63 (10.76)	27.74 (5.52)
Combined	1.04 (0.38)	0.92 (0.37)	24.78 (11.30)	26.70 (5.76)

[a] Numbers in parentheses are standard deviations.

TABLE 6. Actual vs predicted log grade yields for 10- and 12- m log lengths

Type	Grade	N	% N	Volume (m^3)	Volume %
Actual	J	49	63.6	24.9	64.2
	X	28	36.4	13.9	35.8
Predicted 10 m	I	1	1.0	1.6	3.7
	J	94	97.9	41.8	96.0
	X	1	1.0	0.1	0.3
Predicted 12 m	J	81	98.8	42.8	98.3
	X	1	1.2	0.8	1.7

TABLE 7. Log grade yields related to tree dbh

Dbh class (cm)	No. of trees	Total log volume (m^3)	Grade distribution (% log volume)	
			J	X
30.0-34.9	8	5.5	75.6	24.4
35.0-39.9	16	12.0	71.5	28.5
40.0-44.9	13	13.7	76.0	24.0
45.0-49.9	4	5.7	30.8	69.2
55.0-59.9	1	1.9	-	100.0
Combined	42	38.8	64.2	35.8

TABLE 8. Log grade statistics

Grade	No. of logs	Mean top (cm)	Mean Lrf (fbm/m^3)	Std. dev. Lrf (fbm/m^3)	Mean total value ($)	Std. dev. total value ($)	Mean average value ($/$m^3$)	Std. dev. average value ($/$m^3$)
J	49	18.2	239.2	58.71	14.46	9.70	27.19	8.51
X	28	17.5	235.7	66.40	11.67	9.53	22.34	6.75
Combined	77	17.9	238.0	61.21	13.44	9.67	25.43	8.21

4.3.2 Lumber volume and grade yields

Lumber recovery factors obtained from the distorted Douglas-fir mill-run logs are shown in comparison to those obtained from logs in the previous Douglas-fir study in Table 9. In diameter classes with sufficient logs to allow a meaningful comparison, the lumber recovery factors for the distorted fir study exceeded those of the second-growth study. This was a result of the following two factors:

1. The log roughness was slabbed off without detriment to volume recovery because the distorted logs were of a diameter range from which side lumber is not usually obtained.
2. The lumber from the distorted logs was of such low quality because of defects other than wane (lack of wood) that the usual opportunity to upgrade by trimming was not available. Consequently, volume of trim loss was reduced.

TABLE 9. Lumber recovery factors

Top diameter (cm)	Second-growth fir		Distorted fir	
	No. of logs	Lrf (fbm/m^3)	No. of logs	Lrf (fbm/m^3)
10.0-14.9	126	148	28	190
15.0-19.9	161	191	23	218
20.0-24.9	238	248	38	259
25.0-29	257	277	36	292
30.0-34.9	220	292	8	287
35.0-39.9	188	305	2	298
Combined	1190	253	135	249

Lumber recovery factors from logs in the size range sawn in this study are size-dependent. This is illustrated by the least squares fit to the scattergraph of lumber recovery factors shown in Figure 5.

Lumber grade yields obtained from the study logs are shown distributed by lumber dimension, and summarized for all lumber dimensions in Table 10. Less than 2% of the green lumber tallied made the premium grade of Select Structural, and only 22% of the lumber was graded No. 2 or above; in the second-growth Douglas-fir study, 35% of lumber was Select Structural and almost 85% was graded No. 2 or higher. A summary of grade yield is illustrated in Figure 6.

The lumber grader recorded a reason for each lumber grade assigned, making it possible to determine which growth traits had the most effect on grade and value. It was expected that branchiness and sinuosity would be reflected in lumber degrade that was attributable to knots or wane, and that these attributes would be responsible for the majority of degrade in the study lumber.

A distribution of lumber volume by reason for grade assignment is shown in Table 11. While knots and wane were noted as reasons for downgrading 44% of the lumber volume and 49% of the lumber pieces, more than half of the lumber volume was downgraded for excessive rate of growth (less than four annual growth rings per inch). This was unexpected because growth rate was not a factor in the second-growth Douglas-fir study. Distributions of lumber volume by reason for lumber grade assigned are compared in Figure 7.

Growth rate was not a problem in the second-growth Douglas-fir study, because the trees in that study were deliberately selected for their uniform growth rates. The distorted trees, however, grew very rapidly over the first 20 years, and then slowed substantially. In terms of visual grade yields, this rapid initial rate of growth proved undesirable. Moreover, the fact that mean annual increment was decreasing on both the Franklin and Pachena sites makes it unlikely the trees on those sites would "grow out of" their distortions if a short rotation is the goal.

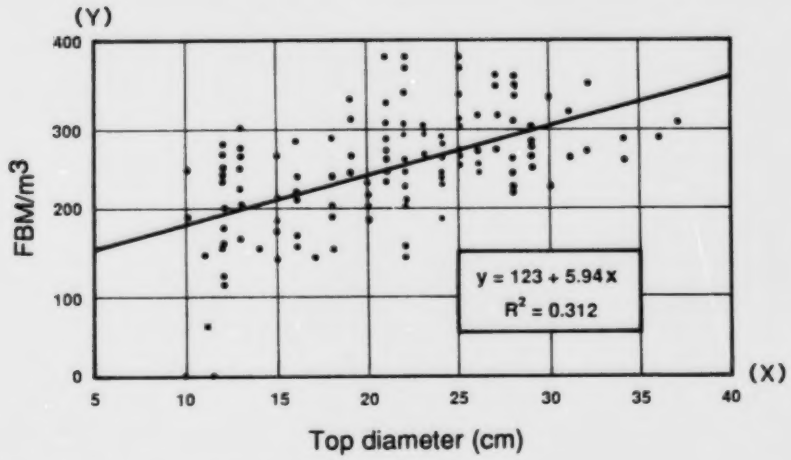

FIGURE 5. Short log lumber recovery factors.

TABLE 10. Distribution of lumber by grade and dimension

	2 x 3		2 x 4		2 x 6		2 x 8		2 x 10		Total	
Grade	Fbm	%	Fbm	%	Fbm	%	Fbm	%	Fbm	%	Fbm	%
Select	-	-	16	0.8	52	1.4	117	3.1	-	-	185	1.9
No. 1	17	100	235	12.3	446	11.6	240	6.3	-	-	938	9.8
No. 2	-	-	161	8.4	392	10.2	435	11.4	23	100	1011	10.5
No. 3	-	-	769	40.2	2286	59.6	2701	70.7	-	-	5757	59.9
Economy	-	-	731	38.2	662	17.2	325	8.5	-	-	1718	17.9
Total	17	100	1912	100	3838	100	3819	100	23	100	9609	100

TABLE 11. Distribution of lumber by grading defect

Defect	No. of pieces	Fbm	% Fbm
Wane	219	2787	29.0
Knots	104	1461	15.2
Shake	1	12	0.1
Slope of grain	2	32	0.3
Growth rate	322	5204	54.2
Mis-manufacture	8	113	1.2
Total	656	9609	100.0

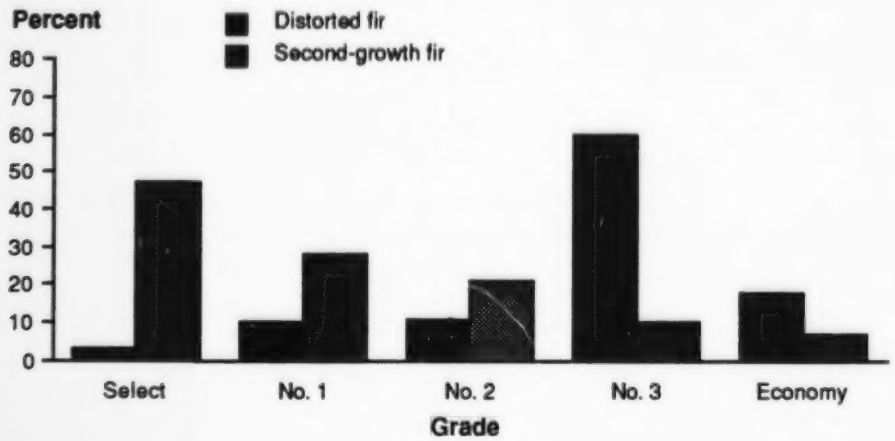

FIGURE 6. Comparative lumber grade distributions.

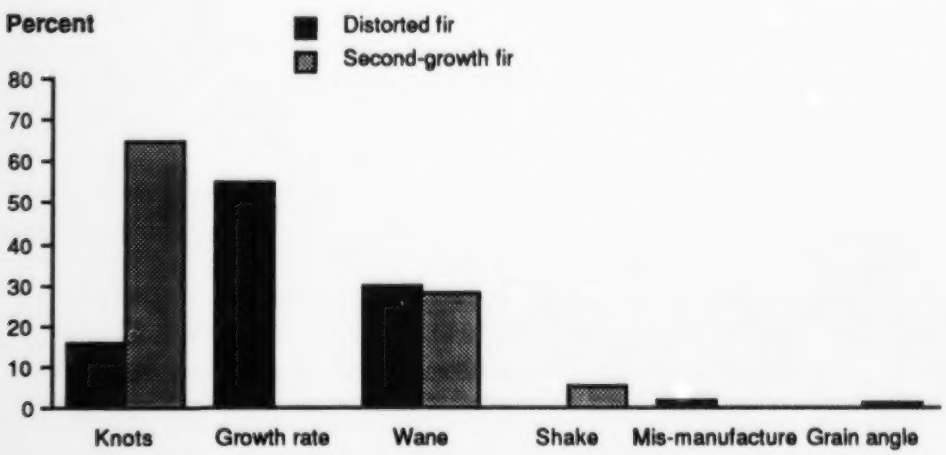

FIGURE 7. Comparative distribution of lumber of grading defect.

4.3.3 Tree values

Average values per cubic metre of wood volume obtained from the distorted trees are compared, for the same dbh classes, to those obtained from the second-growth Douglas-fir study in Table 12. The two sets of tree values were compared by dbh class because size is often the most important determinant of both total and average tree value. The average value of the distorted trees was 43% lower than that of trees of similar size in the second-growth Douglas-fir study. The relationship between tree dbh and total and average value is illustrated in Figures 8 and 9.

Lumber prices used to assign values to the lumber from the distorted trees were the same as those used in the second-growth Douglas-fir study. These are provided in Table 13.

TABLE 12. Average tree values

	Second-growth fir		Distorted fir	
Dbh (cm)	No. of trees	Value ($/m^3)	No. of trees	Value ($/m^3)
20.0-24.9	1	39.22	-	-
25.0-29.9	6	36.25	-	-
30.0-34.9	41	36.80	8	28.20
35.0-39.9	41	42.61	16	26.04
40.0-44.9	41	45.64	13	26.70
45.0-49.9	41	51.03	4	27.36
50.0-54.9	42	53.63	-	-
55.0-59.9	42	53.99	1	22.56
Combined	255	47.04	42	26.70

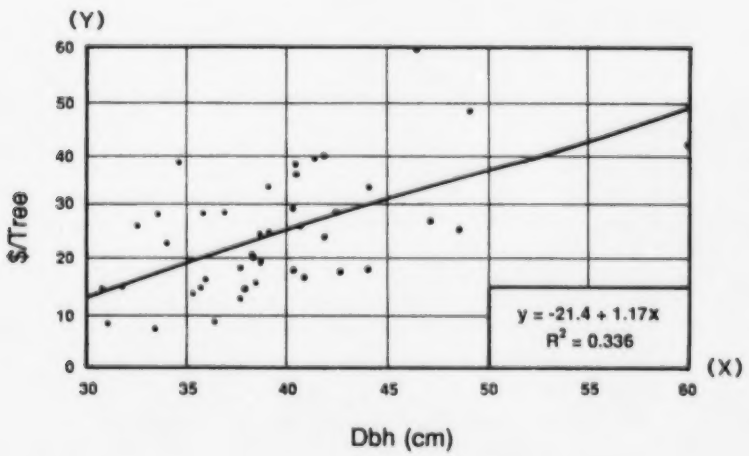

FIGURE 8. Total tree values.

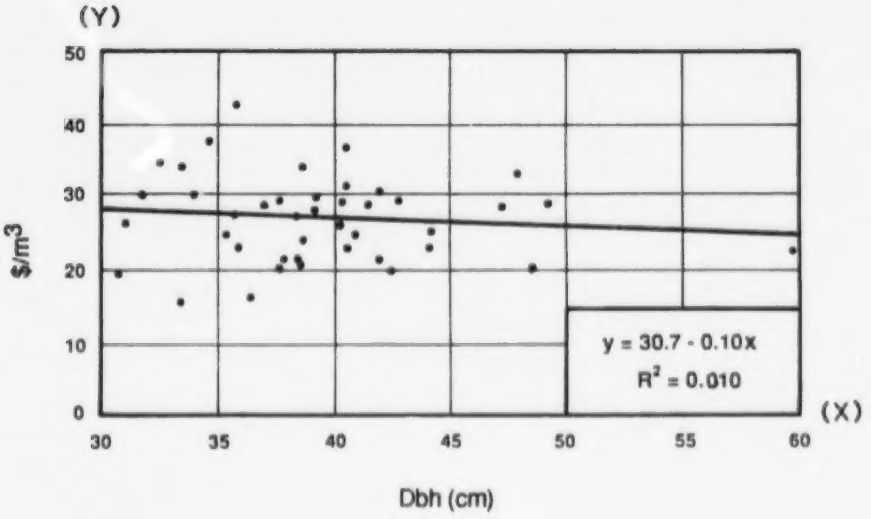

FIGURE 9. Average tree values.

TABLE 13. Lumber prices ($/mfbm)

Lumber dimension (inches)	Grade				
	Select	No.1	No.2	No.3	Economy
2 x 4	192	178	178	121	53
2 x 6	184	170	170	104	51
2 x 8	189	175	175	89	53

4.4 Sinuosity and Branching

Table 14 provides value statistics for the complete combination of branching and sinuosity indices obtained by classing the study trees in the method described. The table, while illustrating the limitations of the sample size, helps to define the probable boundaries of a meaningful classification system for these two growth traits. Although not entirely consistent, some trend is evident to indicate that value declines with increases in branching and sinuosity.

Considerable grouping of the data was necessary to eliminate empty cells and provide some basis for estimating future sample size requirements. Various attempts at grouping culminated in two classifications for each characteristic: moderate and severe. Statistics for these final groups are provided in Table 15. Trees with moderate branching (Index ≤ 4) and moderate sinuosity (Index ≤ 6) had the highest average values obtained, being worth approximately $30/m^3$. A change of either one of the traits to *severe* decreased the average value by 13%, to about $26/m^3$ A change in both traits to *severe* further decreased the value to about $24/m^3$, 20% below the average value of trees in the moderate-moderate class.

An analysis of variance revealed that the differences in average tree value between moderate and severe classes of sinuosity and branching were not statistically significant. Results of the analysis of variance are shown in Table 16. It was determined, based on the mean square error, that a minimum of 20 trees per classification cell would be required to establish that differences in class values of the magnitude recorded here would be statistically significant at the 5% level.

TABLE 14. Average value statistics for sinuosity and branching indices

Branching index		Sinuosity index							
		1	4	6	8	9	12	20	Combined
2	N	1	2	-	-	-	1	-	4
	Mean ($/m^3)	42.89	31.39	-	-	-	32.36	-	34.51
	Std. dev.	-	3.27	-	-	-	-	-	5.92
3	N	1	-	-	-	1	-	-	2
	Mean ($/m^3)	23.80	-	-	-	29.18	-	-	26.49
	Std. dev.	-	-	-	-	-	-	-	3.80
4	N	1	2	3	1	-	4	1	12
	Mean ($/m^3)	28.42	27.76	27.34	36.49	-	20.61	29.80	26.22
	Std. dev.	-	2.58	3.84	-	-	0.89	-	5.19
6	N	3	6	6	1	3	1	-	20
	Mean ($/m^3)	26.54	25.68	26.73	24.62	23.62	22.73	-	25.61
	Std. dev.	7.17	4.98	6.42	-	9.22	-	-	5.78
8	N	1	2	-	-	1	-	-	4
	Mean ($/m^3)	29.41	25.41	-	-	23.08	-	-	25.83
	Std. dev.	-	4.03	-	-	-	-	-	3.51
Combined	N	7	12	9	2	5	6	1	42
	Mean ($/m^3)	29.16	26.93	26.93	30.56	24.62	22.92	29.80	26.70
	Std. dev.	7.54	4.40	5.44	8.39	7.00	4.75	-	5.76

TABLE 15. Average value statistics for grouped sinuosity and branching indices

Branching		Sinuosity		
		Moderate	Severe	Combined
Moderate	N	10	8	18
	Mean ($/m^3)	29.54	26.28	28.09
	Std. dev.	5.65	6.47	6.07
Severe	N	18	6	24
	Mean ($/m^3)	26.35	23.55	25.65
	Std. dev.	5.23	5.87	5.40
Combined	N	28	14	42
	Mean ($/m^3)	27.49	25.11	26.70
	Std. dev.	5.50	6.14	5.76

Sinuosity: MODERATE if sinuosity index ≤ 6
SEVERE if sinuosity index > 6

Branching: MODERATE if branching index ≤ 4
SEVERE if branching index > 4

TABLE 16. Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value	Prob > F
Main effects					
Branching	1	61.49	61.49	1.92	0.17
Sinuosity	1	52.79	52.79	1.65	0.21
Interaction	1	29.70	29.70	0.93	0.34
Error	38	1216.26	32.01		
Total	41	1360.24			

4.5 Growth Rate

The quantity of study lumber downgraded for rate of growth (54%) made it difficult to evaluate the independent effect of branching and sinuosity on tree values. However, it was possible to compare lumber assigned a grade for reason of knots in this study, to similar lumber obtained from the second-growth Douglas-fir study; and to gain some appreciation of how the effect of branching differed when rate of growth was not a factor.

Lumber grades determined by knots only are compared in Table 17. The table shows that branch growth in the distorted trees resulted in knots that limited yields of Select Structural to 13% compared to a yield of 54% obtained in the second-growth Douglas-fir study. However, the table also shows that excessive or oversized branching, considered alone, would have caused less than 15% of lumber from the distorted trees to be graded lower than No. 2 — much less than the 78% of lumber that was graded No. 3 and Economy in the study as a whole.

Subsamples of study lumber obtained for the kiln drying study were used in a further effort to quantify the probable independent effect of knots in lumber downgraded for rate of growth. Fifty pieces of 2 x 6 and 50 pieces of 2 x 8 lumber with obviously excessive rate of growth were re-graded for knots only. This re-grading resulted in no more than 4% of the pieces being graded lower than No. 2 for knots, and confirmed that growth rate rather than branching traits was the growth characteristic most detrimental to tree value.

TABLE 17. Comparative lumber grade distributions for lumber graded by reason of knot size

Lumber grade	Distorted fir			Second-growth fir		
	No. of pieces	Fbm	% Fbm	No. of pieces	Fbm	% Fbm
Select	12	185	12.9	2 650	62 951	53.6
No. 1	44	601	41.0	2 027	42 447	36.2
No. 2	32	475	32.4	496	8 510	7.2
No. 3	11	141	9.6	204	2 949	2.5
Economy	5	59	4.0	40	495	0.4

4.6 Lumber Drying Study

The results of the drying study are summarized in Table 18, which shows the proportion of 2 x 6's and 2 x 8's that would fail to make grade requirements with respect to the drying defects listed. Twist was present in a high proportion of the study lumber (90% of 2 x 6's and 66% of 2 x 8's), but crook proved to be the worst drying defect in terms of lumber being reduced in NLGA grade. Approximately 37% of 2 x 8's had crook greater than the 3/16 inch maximum allowed in the Select and No. 1 Structural grades. Approximately 15% of 2 x 6's had the same degree of crook, but a more liberal grade rule allowance (1/4 inch) limited the proportion of pieces graded below Select and No. 1 Structural to 5%.

The drying study confirmed drying problems already documented for second-growth Douglas-fir (Mackay, 1986). However, an evaluation of the results with respect to sinuosity revealed no additional detrimental effect.

TABLE 18. Lumber grade loss related to drying defects

Defect	Failed to make Select Structural		Failed to make No. 2	
	2 x 6 %	2 x 8 %	2 x 6 %	2 x 8 %
Bow	2.6	-	0.3	-
Crook	5.2	37.1	5.2	11.4
Cup	0.3	2.2	0.3	-
Twist	8.7	0.9	1.3	-

5 CONCLUSIONS

The purpose of this study was to obtain sufficient information about the effect of growth distortion on tree value to (1) determine if it was a significant problem, and (2) make a sound decision about the need for further sampling. Average tree values obtained for the distorted trees selected and milled in this study were 43% lower than those previously obtained for second-growth Douglas-fir. Moreover, the exclusion of trees with severe forks meant that the study trees represented a better quality than was actually available. This shows that concern for the future value of timber stands exhibiting distorted growth is justified, and that the full extent of the problem should be identified.

Branching and sinuosity had a detrimental effect on average tree value, and it was possible to use the variation in value associated with these traits to estimate sample sizes required to quantify their effect reliably. A minimum of 20 trees would be required in each of the four proposed distortion classes to establish that between-class differences in average tree values of the magnitude found in this study are statistically significant at the 5% level.

The study demonstrated that the indices used to classify branching and sinuosity traits provide a means of estimating probable differences in tree values related to the two traits. A broad grouping of these indices into moderate and severe categories appears to be adequate.

Rate of growth proved to be more detrimental to lumber grade yields than did knots, and was primarily responsible for the comparatively low value of the distorted trees. Distorted growth in British Columbia coastal Douglas-fir is generally associated with very rapid rates of growth. Therefore, excessive branching and sinuosity traits may be more important as indicators of excessive growth rates than as independent indicators of low tree value.

6 RECOMMENDATIONS

As a result of the findings in this study, the following recommendations are made:

1. Further sampling should be done to confirm the results of this study, and to determine if the indices developed here are based on the most appropriate criteria for assessing the effect of growth distortion.
2. Some quantitative testing should be conducted to confirm that growth distortion is generally associated with very rapid rates of growth.
3. Engineering tests should be conducted to confirm that visual grades assigned due to excessive growth rate are indicative of actual lumber strength values.
4. Research should be undertaken to develop modified drying practices which will reduce warp that occurs when lumber from second-growth Douglas-fir is kiln dried.

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